Chapter → 01

Q-01

Sketch the atomic structure of copper and discuss why it is a good conductor and how it's structure is different from that of germanium, silicon and gallium arsenide.

Solution: The atomic structure of copper is shown in figure: "C".

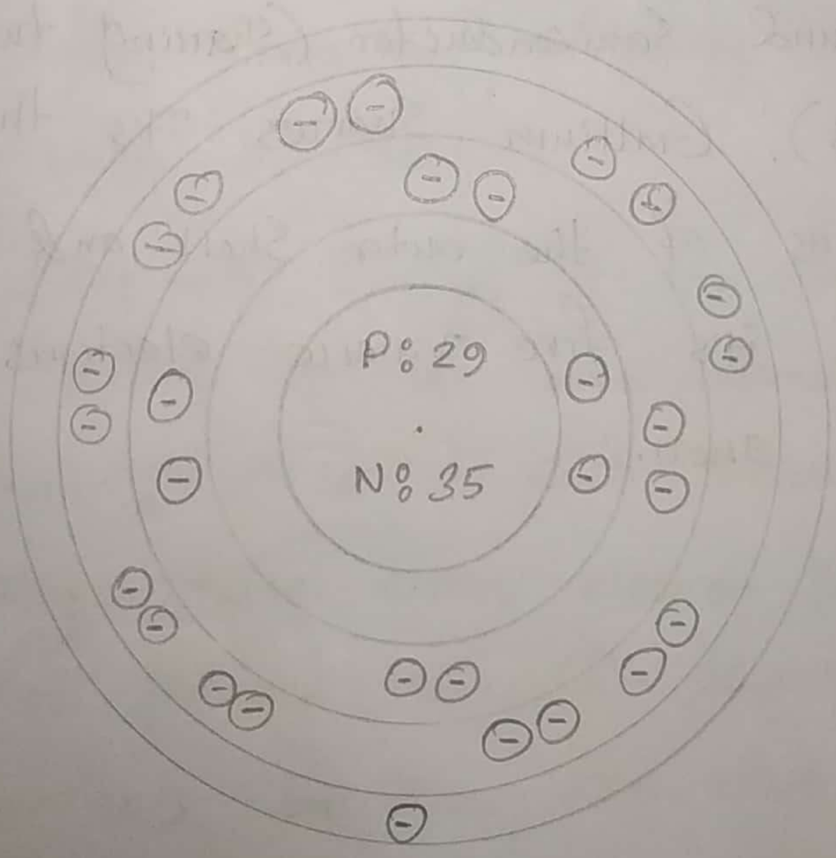

Figure: "C"

Copper is a good Conductor due to the Pressence of one electron at the outer Shell So it Conducts easily. It's Structure is different from germanium, Silicon and gallium arseide as they are Semiconductors, where germanium and Silicon are Single Crystal Semiconductors, where germanium and Silicon ~~and~~ are Single Crystal Semiconductors, having four electrons at the outer Shell and gallium arsenide is a Compound Semiconductor (Sharing two different atoms). Gallium Shares it's three Valence electrons of the outer Shell and arsenic Shares it's five valence electrons of the Outer shell.

Q-02

In your own words, define an intrinsic material, a negative temperature coefficient, and covalent bonding.

Solution:

(I) Intrinsic material (undoped material) is any semiconductor that is chemically pure, free of any impurities.

(II) Negative temperature coefficient is the increase level of conductivity with the application of heat.

(III) Covalent bonding is the link between two atoms of the same element or of elements close to each other in the periodic table where electron pairs are shared between them. It occurs mainly in nonmetals but can also occur in metals.

Q-04

(a) How much energy in Joules is required to move a charge of 12 μC through a difference in potential of 6V?

(b) For part (a), find the energy in electron-Volts

We know,

$$W = QV$$
$$= (12\times10^{-6})\times 6$$
$$= 72\ \mu J$$

(Answer)

Given,

$Q = 12\ \mu C$

$V = 6V$

(b)

As each electron volt of energy is equivalent to 1.6×10^{-19} J,

Therefore,

$$W = \frac{72\times10^{-6}}{1.6\times10^{-19}}$$

$$W = 4.5\times10^{14}\ eV$$

(Answer)

Q-05

If 48eV of energy is required to move a charge through a potential difference of 3.2 V, determine the charge involved.

Solution:

We know, that the energy required to move a charge between two points with difference is potential is,

$$W = QV$$

However, the energy in this formula is required to be in joules,

$$W = 48eV$$
$$= 48 \times (1.6 \times 10^{-19})$$
$$= 76.8 \times 10^{-19} J$$

We know,

$$Q = \frac{W}{V}$$
$$= \frac{76.8 \times 10^{-19}}{3.2}$$
$$= 2.4 \times 10^{-18} C$$

(Answer)

Given,

$W = 76.8 \times 10^{-19} J$

$V = 3.2V$

$Q = ?$

Q-07

Describe the difference between n-type and p-type Semiconductor materials.

Solution: The difference between n-type and p-type Semiconductor materials is:

n-type	p-type
(i) In n-type Semiconductor, impurity added creates extra electrons So it is known as donor atom	(i) While in p-type Semiconductor, impurity added creates vacany of electrons So it is known as acceptore atom.
(ii) Electrons are the majority Carriers and holes are the minority Carriers	(ii) Holes are the majority Carrier and electrons are the minority Carriers

Q-08

Describe the difference between donor and acceptor impurities.

Solution:

The differences between donor and acceptor impurities are :-

Donor impurities:	Acceptor impurities
(I) Donor impurities are the elements added to a semiconductor in order to increase the electrical conductivity of the semiconductor through free or unbounded electrons.	(I) Acceptor impurities are the elements added to a semiconductor in order to increase the electrical conductivity by creating holes. ~~The accept~~
(II) The donor impurities are from group V elements having five valence electrons.	(II) The acceptor impurities are from group III elements having three valence electrons.
(III) When the semiconductor is doped impurities, it is called an n-type material.	(III) When the semiconductor is doped by acceptor impurities, it is called a p-type material.

Q-09

Describe the difference between majority and minority Carriers.

Solution: The difference between majority and minority Carriers are:

Majority Carriers	Minority Carriers
(i) Majority Carriers are the most abundant Charge Carriers.	(i) Minority Carriers are the less abundant charge Carriers
(ii) In n-type Semiconductors they are electrons, while in p-type Semiconductors they are holes	(ii) In n-type Semiconductor they are holes, while in P-type Semiconductor they are electrons.

Q-10

Sketch the atomic Structure of Silcon and insert an impurity of arsenic as demonstrate for silicon in fig. 1.7.

Solution:

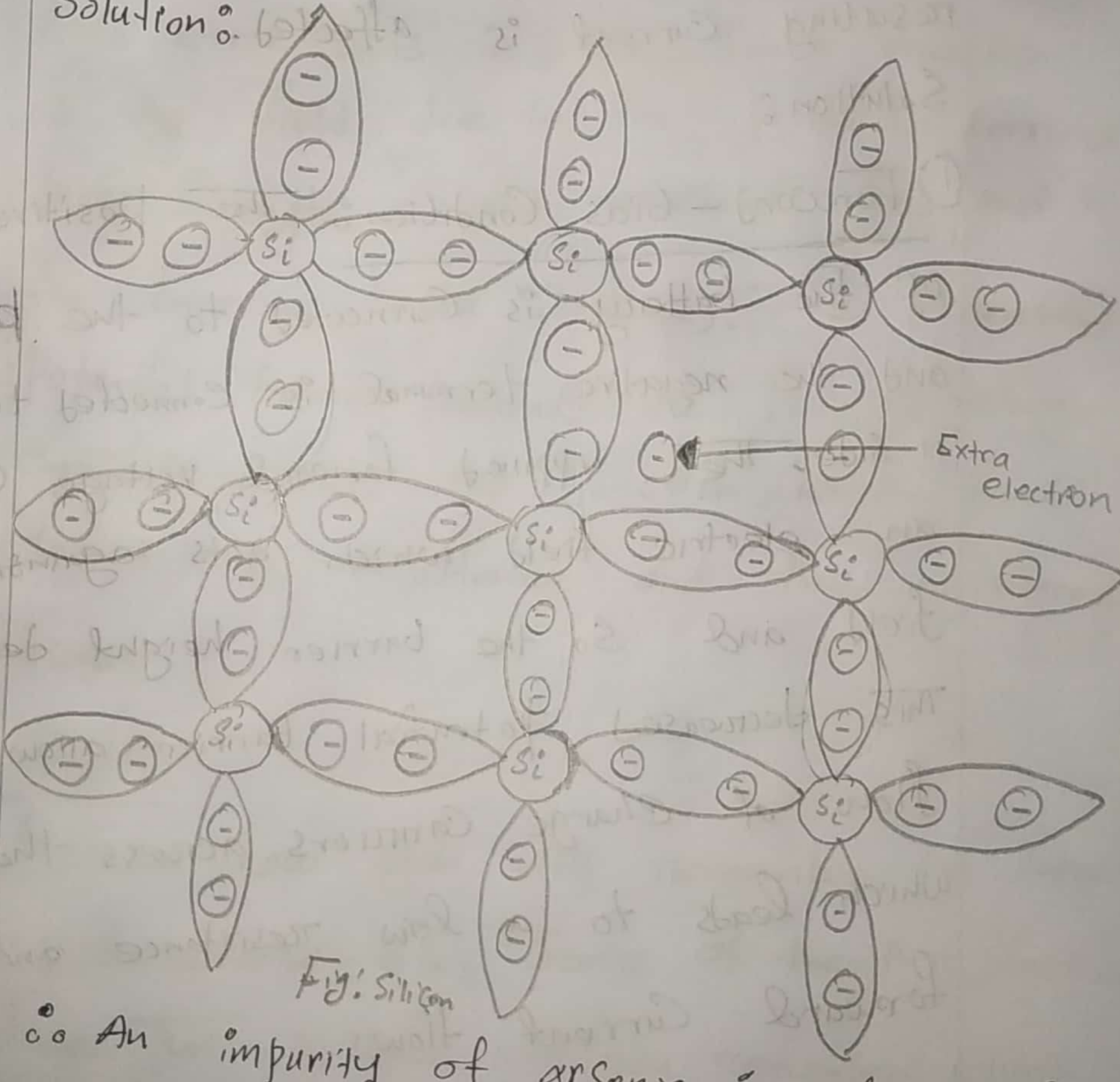

Fig: Silicon

∴ An impurity of arsenic is inserted for the atomic Structure of Silicon

Q-13

Describe in your own words the conditions established by forward- and reverse-bias conditions on a p-n junction diode and how the resulting current is affected.

Solution:

① Forward-bias Condition: The positive terminal of the battery is connected to the p-side. and the negative terminal is connected to the n-side. The applied forward voltage creates an electric field which acts against the field and so the barrier height decreases. This decreased potential barrier allows the flow of charge carriers across the junction which leads to a low resistance and thus forward current flows.

② **Reverse- bias Condition:** The negative terminal of the battery is Connected to the p-side and the positive terminal is Connected to the n-side The applied reverse Voltage Creates an electric field which acts in the Same direction as the field due to the potential barrier, this Strengthens the resultant field and So the barrier height increases. This increased Potential barrier prevents the flow of charge Carriers across the junction which leads to a high resistance and thus no Current flows

Q-14

Describe how you will remember the forward -and reverse-bias State of the p-n junction diode. That is, how will you remember which Potential (positive or negative) is applied to which terminal?

Solution :

The positive terminal is connected to the p-side and the negative terminal is connected to the n-side. While in the reverse-bias, the negative terminal is ~~Come~~ connected to the p-side and the positive terminal is connected to the n-side.

Q-17

(a) Using Eq. (1.2), determine the diode current at 20°C for a silicon diode with $n=2$, $I_s = 0.1\ \mu A$ at a reverse-bias potential at $-10V$.

(b) Is the result expected? why?

Solution:

(a)

We know,

$$I_D = I_S\left(e^{V_D/nV_T} - 1\right)$$

$$= 0.1\times10^{-6}\times\left(e^{(-10)/(2)(0.02527)} - 1\right)$$

$$\therefore I_D = 0.1\,\mu A$$

Given,
$I_s = 0.1\,\mu A$
$= 0.1\times10^{-6}$,
$V_D = -10V$,
$n = 2$.

(b) Since the current that exists under reverse-bias conditions is called the reverse saturation current and is equal to I_S,

Thus, the value calculated in part-(a) is expected.

Q-19

Given a diode current of 6 mA, $V_T = 26\,mV$, $n = 1$ and $I_s = 1\,nA$, find the applied voltage V_D

Solution: Using the diode current equation,

$$I_D = I_S (e^{V_D / nV_T} - 1)$$

$$0.006 = 1\times10^{-9} \times (e^{V_D/(1)\times(0.026)} - 1)$$

Hence,

$$\therefore 6\times10^{6} + 1 = e^{V_D/0.026}$$

$$V_D = (0.026) \cancel{\times} (6\times10^{6}+1)$$

$\therefore$ ~~$V_D = 405.79\,mV$~~ ~~(Answer)~~

$$\therefore V_D = 156\,mV.$$

Q-20

ⓐ Plot the function $y = e^x$ for x ~~from~~ from 0 to 10. Why is it dificult to plot?

ⓑ what is the value of $y = e^x$ at $x = 0$?

ⓒ Based on the results of part (b), why is the factor -1 important in eq (1.2)?

Solution:

ⓐ

x	$y = e^x$
0	1
1	2.718
2	7.389
3	20.086
4	54.598
5	148.413
6	403.429
7	1096.63
8	2980.958
9	8103.084
10	22026.466

It is difficult to plot because the scale is large, since for the range of x from 0 to 10, the range of y ~~of~~ is from 1 to 10, the range of y is from 1 to 22026.466.

Thus, as the value of x increases, the curve becomes almost vertical.

(b)

At $x=0$, $y=e^{0}=1$

$\therefore y=1$

(c) The factor -1 is important because in case $V_D=0V$, $e^{0}=1$.

Thus, $I_D=I_S(1-1)=0mA$.

Q-21

In the reverse-bias region the saturation current of a silicon diode is about $0.1\mu A$ ($T = 20°c$). Determine it's approximate value if the temperature is increased $40°c$.

Solution: In the reverse-bias region, the reverse saturation current of a silicon diode doubles for every $10°c$ rise in temperature

Thus,

T	I_s
$20°c$	$0.1\mu A$
$30°c$	$2(0.1\mu A) = 0.2\mu A$
$40°c$	$2(0.2\mu A) = 0.4\mu A$
$50°c$	$2(0.4\mu A) = 0.8\mu A$
$60°c$	$2(0.8\mu A) = 1.6\mu A$

$\therefore$ The saturation current increased $2^4 = 16$ times

Thus, it's approximate value when the temperature is increased is $1.6\mu A$. $I_s = 1.6\mu A$

(Answer)

Q-24

Describe in your own words the meaning of the word ideal as applied to a device or a system.

Solution: Ideal means that the devices or System has ideal Characteristics. It is referred mainly to the mathematical description and not really common in real life.

Q-25

Describe in your own words the Charactorist-ics or the ideal diode and how they determine the on and off states of the device: That is, describe why the Short-Circuit and open-Circuit equivalents are appropriate.

Solution:

An ideal diode is a diode that acts like a perfect conductor that conducts perfectly in the forward bias and does not conduct in the reverse bias.

In case of forward-bias (ON): The current is greater than zero, the voltage across it is negligible or zero and the diode acts as a short-circuit. Thus, the short-circuit equivalent is appropriate since in short-circuit the resistance between the node is zero and there is negligible voltage drop or zero voltage so it conducts.

While in case of reverse-bias (OFF): The curren is zero, the voltage across is less than zero since ~~in~~ it does not conduct and the diode acts as an open circuit. Thus, the open-circuit equivalent is appropriate since in open-circuit no current flows and thus no electric energy flows so it does not conduct.

Q-26

What is one important difference between the characteristics of a simple switch and those of an ideal diode?

Solution: The most important difference between the characteristics of a simple switch and those of an ideal diode is that the switch conducts in either direction while the ideal diode conducts only in one direction.

Q-27

Determine the static or dc resistance of the commercially available diode of fig.1.15 at a ward current of 4mA.

Solution:

Given,

$I_D = 4mA.$

$V_D = 0.7V.$

Then, $R_{DC} = \frac{V_D}{I_D}$

$= \frac{0.7}{0.004}$

$= 175\ \Omega$

(Answer)

Q-29

Determine the Static or dc Resistance of the commercially available diode of fig-1.15 at a forward current of 4mA.

Solution:

$V_D = -10V$, $I_D = I_s = -0.1mA$

$R_{DC} = \frac{V_D}{I_D} = \frac{10V}{0.1\mu A} = 100m\Omega$

$V_D = -30V$, $I_D = I_s = -0.1\mu A$

$R_{DC} = \frac{V_D}{I_D} = \frac{30V}{0.1\mu A} = 300m\Omega$

Q-31

(a) Determine the dynamic (ac) resistance of the Commercially available diode of fig 1.15 at a forward Current of 10 mA using eq. 1.5.

(b) Determine the dynamic (ac) resistance of the diode of fig 1.15 at a forward current of 10mA using Eq (1.6).

(c) Compare Solutions of part (a) and (b).

Solution: From fig 1.15, we take a Swing of 1mA above and below the Specified diode Current $I_D = 10mA$,

Therefore,

At $I_D = 9mA \Rightarrow V_D = 0.8V$

At $I_D = 11mA \Rightarrow V_D \approx 0.81V$

According to ~~fig~~ eq (1.5) we get,

$$r_d = \frac{\Delta V_D}{\Delta I_D} = \frac{0.81V - 0.8V}{11mA - 9mA} = 5\Omega$$

(Answer)

(b)

According to eq (1.6) we get,

$$r_d = \frac{26mV}{I_D} = \frac{26mV}{10mA} = 2.6\Omega$$

(c) The two solutions of part (a) and (b) are relatively close.

(a) Using eq (1.5), $r_d = 5\Omega$

(b) Using eq (1.6), $r_d = 2.6\Omega$

Q-34

Determine the average ac resistance for the diode of fig. 1.15 for the region between 0.6V and 0.9V.

Solution:

From fig-1.15 we apply equation,

$$r_{av} = \frac{\Delta V_d}{\Delta I_d}$$

$$= \frac{0.9V - 0.6V}{20mA - 2mA}$$

$$= \frac{0.3V}{18mA}$$

$$= 16.7\,\Omega$$

(Answer)

Q- 35

Determine the ac resistance for the diode of fig 1.15 at 0.75 V and Compare it to the average ac resistance obtained in Problem 34.

Solution:

We know,

$$r_{av} = \frac{\Delta V_d}{\Delta I_d} = \frac{0.1V}{4.45\times10^{-3}A} = 22.47\Omega$$

(Answer)

Q- 36

(a) Find the piece-wise-linear equivalent circuit for the diode of fig 1.15. Use a Straight line segment that intersects the horizontal axis at 0.7V and best approximates the Curve for the region greater than 0.7V.

Solution :

To get piecewise linear equivalent circuit fo the diode,

$$r_{av} = \frac{\Delta V_D}{\Delta I_D}$$

$$= \frac{0.9V - 0.7V}{20mA - 4.55mA}$$

$$= \frac{0.2}{15.45mA}$$

$$= \frac{0.2}{15.45 \times 10^{-3} A}$$

$$= 12.94\Omega$$

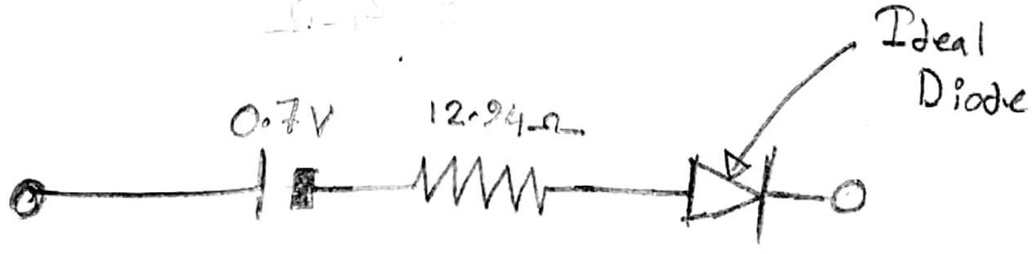

Figure : 1

Q-37

Repeat Problem 36 for the diode of Fig. 1.27.

Solution:

we apply formula,

$$r_{av} = \frac{\Delta V_D}{\Delta I_D}$$

$$= \frac{0.8V - 0.7V}{25mA - 0mA}$$

$$= \frac{0.1V}{25mA}$$

$$= \frac{0.1V}{25 \times 10^{-3} A}$$

$$= 4\Omega$$

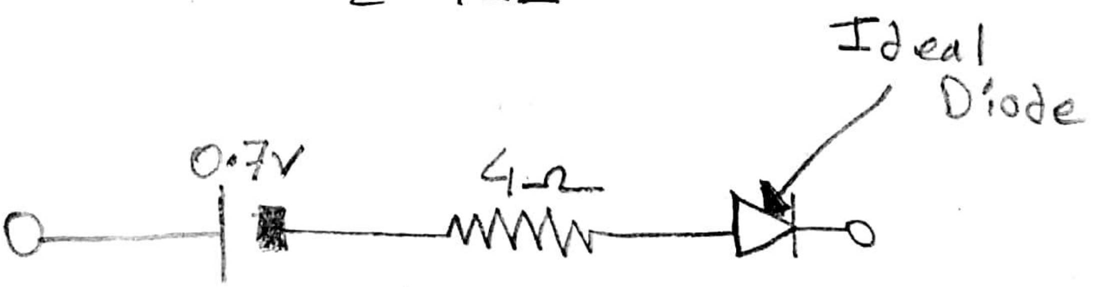

Figure: 02

Q-38

Find the piecewise-linear equivalent circuit for the germanium and gallium arsenide diodes of Fig. 1.18.

Solution:

For gallium arsenide diode,

$$V_K = 1.2V$$

Using r_{av} on two points from linear region,

$$r_{av} = \frac{\Delta V_D}{\Delta I_D}$$

$$= \frac{1.3 - 1.2}{0.020 - 0.004}$$

$$= 6.25\ \Omega$$

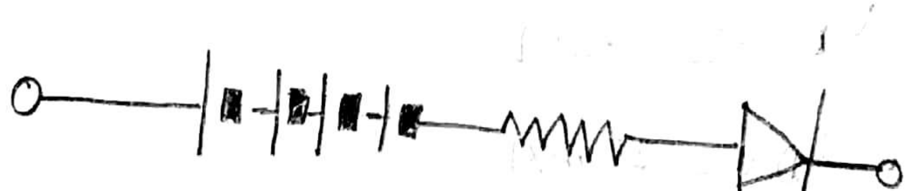

Figure : 03

Chapter → 02

Q-1

(a) Using the Characteristics of fig 2.152 b, determine I_D, V_D and V_R for the circuit of fig: 2.152 a.

(b) Repeat part (a) using the approximate model for the diode and compare results.

(c) Repeat part (a) Using the ideal model for the diode and Compare results.

Solution:

The load line will intersect at

$$I_D = \frac{E}{R} = \frac{12V}{150\Omega} = 16mA \text{ and } V_D = 12V$$

(a) $V_{DQ} \cong 0.85V$

$I_{DQ} = 15mA$

$V_R = E - V_{DQ} = 12V - 0.85V = 11.15V$

(b) $V_{DQ} \cong 0.7V$

$I_{DQ} \cong 15mA$

$V_R = E - V_{DQ} = 12V - 0.7V = 11.3V$

(c)

$V_{DQ} \cong 0V$

$I_{DQ} \cong 16mA$

$V_R = E - V_{DQ} = 12V - 0V \doteq 12V.$

For (a) and (b), levels of V_{DQ} and I_{DQ} are quite close. Levels of part (c) are reasonably close but as expected due to level of applied voltage E.

Q-02

(a) Using the Characteristics of fig. 2.15 2b, determine I_D and V_D for the circuit of fig: 2153.

(b) Repeat part (a) with $R = 0.47k\Omega$

(c) Repeat part (a) with $R = 0.68k\Omega$

(d) Is the level of V_D relatively close to 0.7V in each case.

Solution:

(a) $I_D = \frac{E}{R} = \frac{6V}{0.2k\Omega} = 30mA$

The load line extends from $I_D = 30mA$ to $V_D = 6V$,

$V_{DQ} \cong 0.95V$,

$I_{DQ} \cong 25.3mA$.

(b) $I_D = \frac{E}{R} = \frac{6V}{0.47k\Omega} = 12.77mA$.

The load line extends from $I_D = 12.77mA$ to $V_D = 6V$

$V_{DQ} \cong 0.8V$, $I_{DQ} \cong 11mA$

(c) $I_D = \frac{E}{R} = \frac{6V}{0.47k\Omega} = 8.82mA$.

The load line extends from $I_D = 8.82mA$ to $V_D = 6V$

$V_{DQ} \cong 0.78V$, $I_{DQ} = 18mA$.

(d) The resulting values of V_{DQ} are quite close, while I_{DQ} extends from 7.8mA to 25.3mA.

Q-03

Determine the value of R. for the circuit of fig : 2.153 that will result in a diode current of 10mA if E = 7v. Use the characteristics of fig. 2.152 b for the diode.

Solution:

Load line through $I_{DQ} = 10mA$ of characteristics and $V_o = 7v$ will intersect I_D axis as 11.3mA

$$I_D = 11.3mA = \frac{E}{R} = \frac{7V}{R}$$

with $R = \frac{7V}{11.3mA}$

$= 619.47 k\Omega$

$\cong 0.62 k\Omega$

$R = 0.62 k\Omega$ is a standard resistor.

Q-04

(a) Using the approximate characteristics for the Si diode, determine V_D, I_D and V_R for the circuit of fig: 2.154.

(b) Perform the same ~~ang~~ analysis as part (a) using the ideal model for the diode.

Solution:

(a)
$$I_D = I_R = \frac{E - V_D}{R}$$

$$= \frac{30V - 0.7V}{1.5\ k\Omega}$$

$$= 19.53 mA$$

$$V_D = 0.7V, \quad V_R = E - V_D$$

$$= 30V - 0.7V$$

$$= 29.3V$$

(b)

$$I_D = \frac{E - V_D}{R}$$

$$= \frac{30V - 0V}{1.5 k\Omega}$$

$$= 20mA$$

$V_D = 0V$, $V_R = 30V$

Yes, Since $E > V_T$ the levels of I_D and V_R are quite close.